European Scientific Journal March edition vol. 8, No.5 ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431

UDC: 330.341:004.7(100)

IT AND ECONOMIC PERFORMANCE
A CRITICAL REVIEW OF THE EMPIRICAL DATA

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Abstract

This study undertakes a critical review of the research on the multi-significant issue of the correlation between IT investments and economic performance at a micro and macroeconomic level. The aim of this study is to shed light on the interaction of IT with the economy, at corporate, industry and national level and document it' s contribution to productivity and therefore to economic growth. The study concludes that there is a positive effect of IT investments on both the two leading economic indicators, productivity and economic growth, in all aspects, but is something that needs further research so as to find a more clear and risk adjusted relation.

Keywords: IT, Economic Performance, Growth, Productivity

"You can see the computer age everywhere but in the productivity statistics"[1]

Introduction

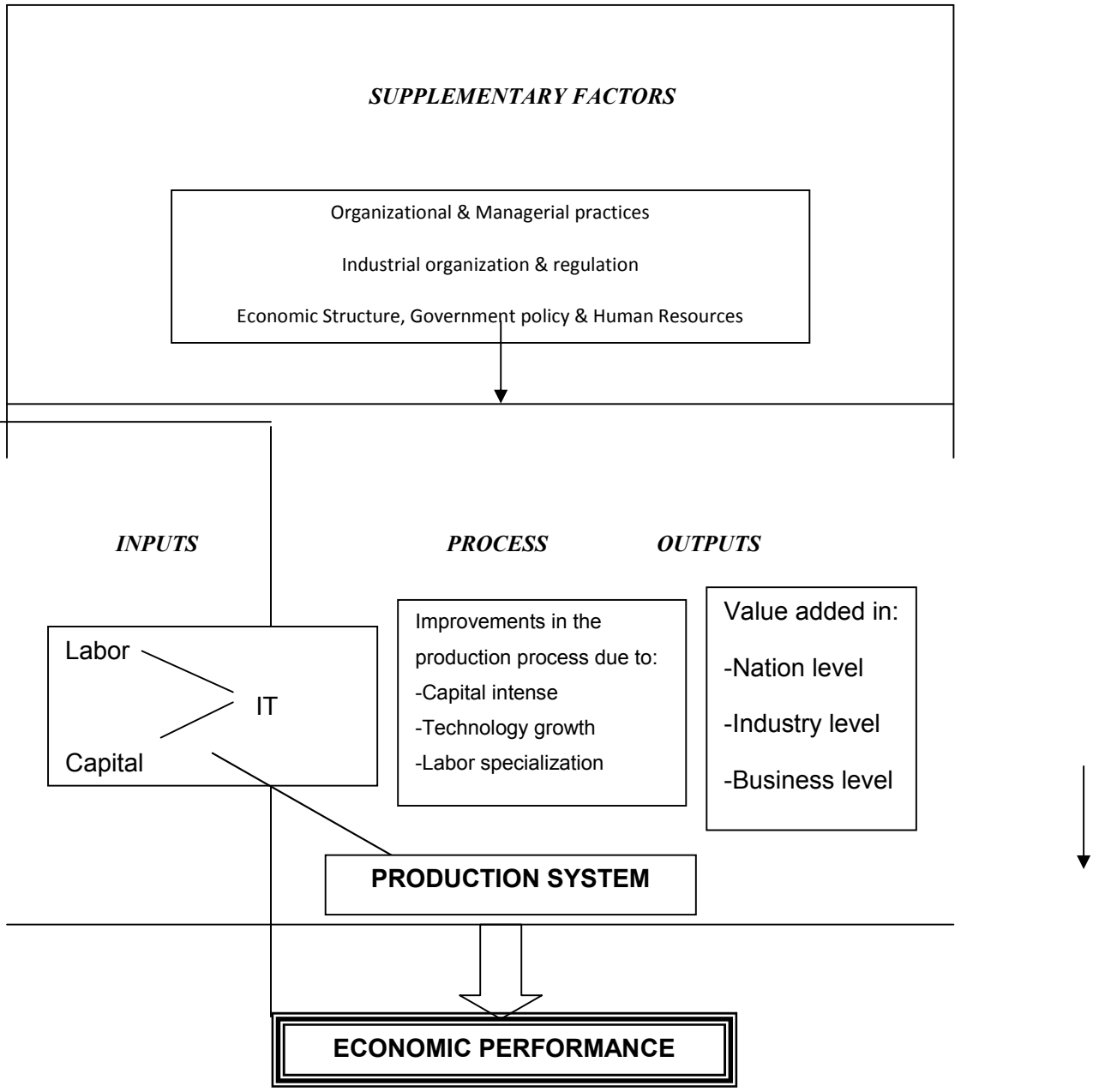
For many years exists a serious debate on whether the revolution of Information Technology (IT) has beneficial impact on productivity. Several studies back to the 80's had shown correlation between the IT investments and the productivity in the US economy, a situation referred to as the productivity paradox or Solow paradox. Since then, a decade of research in business and nation level, has proved that the impact of IT investments on labor productivity and hence on economic growth is not only positive but also significant. In this paper is attempted a review of a large number of scientific articles referring to information technology and productivity in micro and macro level. This is achieved with the use of a general framework in order to categorize the research topics that results to the understanding of the knowledge that has been accumulated until today and makes the road for new discoveries and useful conclusions in this very important scientific field. The final conclusion

[1] Robert Solow, New York Review of Books, July 12, 1987

rejects the productivity paradox and this is easily perceived from the fact that IT is not simply a tool for automation of the existing procedures, but recommends an inducement for organizational changes that can lead to additional production benefits. Moreover, in spite of the fact that during the mid 90's the world witnessed a drastic reduction in IT investments and the collapse of many internet related companies, this review shows that we shouldn't ignore the fundamental changes that have occurred as a result of corporate IT investments and also that these benefits are transmitted to the real economy, with the innovating enterprises leading the way.

First of all, in order to organize the research and identify the key points and the gaps as well, the following scheme is cited so as to depict the aggregate findings.

Diagram 1: Aggregate table of research findings



Moving from left to right, the diagram underlines the various inputs (labor and capital) in the production process and the supplementary factors that affect it and allow the assessment of the contribution of those inputs to the outputs (value added, GDP) and the several exported results (economic growth, profitability, labor productivity and consumer surplus). In addition, it goes further by separating between business, industry and national level analysis.

Before going further with the thorough analysis per level, it is very important to specify two fundamental terms, investment on IT and economic performance, as well as to point out the crucial role of IT to the production process and the aggregate impact on the economy.

In the IT and productivity studies, it is of major importance to discriminate capital to its core categories of investment, IT and non-IT. With the general term IT we mean investments on computers and telecommunications and additionally to the related services, equipment (hardware) and software. As for the importance of IT as a percentage of total capital investment, the next table is cited.

Table 1: Share of ICT investments to total investments

		Australia	Canada	Finland	France	Germany	Italy	Japan	United Kingdom	United States
IT equipment	1980	2.2	3.9	2.0	2.5	4.6	4.1	3.3	2.9	5.1
	1990	5.5	4.5	3.6	3.5	5.5	4.2	3.8	6.0	7.0
	1995	8.4	5.7	4.0	3.9	4.6	3.5	4.6	8.6	8.7
	2000	7.2	7.9	2.9	4.4	6.1	4.2	5.2	8.4	8.3
Communications equipment	1980	4.0	3.0	3.2	2.9	3.9	4.0	3.4	1.6	7.1
	1990	3.8	3.8	3.9	3.2	4.8	5.7	4.0	2.0	7.5
	1995	4.7	4.0	9.3	3.5	4.2	6.7	5.3	3.6	7.3
	2000	5.6	4.2	15.3	3.9	4.3	7.2	6.9	3.6	8.0
Software	1980	1.1	2.2	2.6	1.3	3.6	1.7	0.4	0.3	3.0
	1990	4.6	4.9	5.2	2.6	3.7	3.8	3.1	2.1	8.0
	1995	6.4	7.1	9.2	3.5	4.5	4.3	4.0	3.5	10.1
	2000	9.7	9.4	9.8	6.1	5.7	4.9	3.8	3.0	13.6
ICT equipment and software	1980	7.3	9.1	7.8	6.8	12.2	9.7	7.0	4.8	15.2
	1990	13.9	13.2	12.7	9.4	13.9	13.7	10.8	10.1	22.5
	1995	19.5	16.8	22.5	10.8	13.3	14.4	13.8	15.6	26.1
	2000	22.5	21.4	28.0	14.4	16.2	16.3	16.0	15.0	29.9

Source: Colecchia & Schreyer (2002)

The term economic performance can be translated with a variety of ways in every level of analysis. In national level, where a major part of the scientific debate has focused, it usually refers to economic growth, labor productivity and consumer welfare. (Diagram 1). Economic growth is the percentage change in GDP and is measured in national level. Labor

productivity is a measure of efficient utilization of human resources so as to produce value. It allows the economy to provide low cost goods and services in relation to the consumers' incomes and so as to be competitive in the global markets. It is obvious that the rate of labor productivity makes up an indicator of companies' economic performance. The more productive a company is in comparison with its rivals, the higher levels of profitability it enjoys leading to the achievement of greater economic performance. Of course, as it will be shown further in the paper, competition imposes to all the business players to focus on as much productivity they can reach in order to avoid losing market share and finally, get out of the game. This implies the continuous effort for improvements in the production methods, cost reduction and price squeeze, with direct benefit for the consumers, known as consumer surplus.

Due to the clarification of the main terms, now we can proceed to the next level which consists of the individual analysis per level.

Corporate Level

Though the productivity paradox as initially formulated, focused on national level, the real investments on IT take place primarily from companies that are interested in their own performance and not to the country as a whole. Given that IT investments improve the aggregate productivity, this doesn't mean that enterprises individually enjoy the same benefits. In fact, significant social benefits that increase the consumer welfare may be created, but don't have the same impact in companies. So as, it is of great importance the issue of IT investments' effects on business level.

Early studies during the decades of '80 and '90 weren't able to evince the beneficial influence of IT due to the lack of data and minor sampling measures. More discouraging were the studies that concerned the services providing companies, like banks and insurance companies, where the results showed small or non-existent correlation between IT and productivity in spite of the fact that in these sectors becomes very difficult the measurement and evaluation of the results. The aforementioned studies highlighted the importance of accurate measurements of the findings, especially in technology intense companies where the bigger investments on IT took place. At the dawn of the 90s, more extensive researches were carried out in large US enterprises with the use of data from market analysis companies, experts and in according to the financial data from reliable sources. These studies used econometric methods in order to relate the corporate output (in form of value added) to a sum

of inputs, including the work hours and the IT capital stock and evaluate the marginal product or the output elasticity of IT (increase in value added related to 1% increase in IT investments). The results concluded that IT investments contribute to corporate productivity and show higher marginal returns in comparison to non-IT investments. This remark relies on the better, bigger and more precise data, on the more analytic research tools and on the higher levels of investments on IT. On the other side, many unanswered issues are generated concerning the range of the positive react and mainly in comparison to non-IT investments. The higher marginal product from other investments in capital is translated by several scholars as "additional returns" or as I personally call them "side returns", which have to be adjusted in that way so as to take into consideration the technological depreciation leading in lower net results. Of course, there are studies that with the incorporation of the depreciation (up to 42% per year), end up in higher net results given the estimation that many companies invest in IT. It is very important at this point to mention that most studies don't include the costs of supplementary investments, such as education and specialization that in some cases can be larger than the real direct investments on IT. With the addition of those expenditures, the results may be even more mediocre in combination with bigger standard deviations in results as proved in many studies. Despite the emerging questions, it is still possible an initial positive relation between IT and productivity for a variety of reasons. IT investments pose higher risk by others and that's why companies expect much more benefits in order to cover the additional created risk. Most of the studies don't take into account the impact of this risk. Moreover, it is possible for adjusted costs to exist. It is difficult and costly for companies to introduce new innovations regardless of the continuously reducing prices of IT products. This is due to the delays in the development of new technologies, the withdrawal of older systems and the changes in practices that don't allow the achievement of the optimal level of investments on IT. Recent studies highlight more unanswered issues, like the controversial results per industry and the significance of the right timing to fulfill the invest, as long as the different time periods of the returns with the presence of lags. Two factors are responsible for the wide differentiation between various companies. First of all, the particular characteristics of every company, like the market place, reputation and goodwill or the capability of the executives that affect the strategic choices of the company and hence, the earning of additional benefits by IT. Secondly, the differences in organizational structure, strategy and administration methods that cause restructuring and redesign of the procedures, may affect the final result.

Concerning the effect of IT capital on the measures of financial performance, such as market value and profitability, the results are controversial due to the lack of instant correlation between them. Despite the previous findings which showed that IT investments can influence directly the company's outputs and many organizational indices, financial performance is determined by a broader variety of strategic and competitive factors that exceed the productivity limits. Brynjolfsson and Yang (1997) found that every IT US dollar was related to 5$ up to 20$ additional capitalization for public organizations proving the connection between IT and financial valuation, but stressing that this is a result of important non measurable supplementary organizational practices. In the matter of profitability, there is no clear relation, as IT investment affects directly productivity and leads to consumer welfare, but don't necessarily improves the profit levels. The data and model practices are not in position to give as a clear correlation between IT and profitability, but during the evolution of these models incorporating more factors, it is expected that they will finally prove this relation.

Industry Level

In spite of the fact than in corporate level, studies have given serious results and have proceeded the research in satisfactory level, in industry level the research effort encountered many difficulties due to lack of data. Nevertheless, a number of studies at the end of the 90s, have shown that the growth of labor productivity has accelerated in various industry sectors during the period 1995-9 in the US economy. A research by Gordon (2000) came to the conclusion that the improvement of labor productivity focused on the production sector of durable goods and especially on IT industries, though more recent studies highlighted a speed-up in non durable goods as well. Studies by the Council of Economic Advisors (CEA) are in favor of a positive result ranging from low to very high levels. This is identified by the following Table 1

Table 2: Rate of labor productivity growth, 1989-1999

Industry	1989-1995	1995-1999	Change
Private industries	0.88	2.31	1.43
Agriculture	0.34	1.18	0.84
Mining	4.56	4.06	-0.50
Construction	-0.10	-0.89	-0.79

Manufacturing	3.18	4.34	1.16
Durable goods	4.34	6.84	2.51
Nondurable goods	1.65	1.07	-0.59
Transportation	2.48	1.72	-0.76
Trucking	2.09	-0.78	-2.82
Air transportation	4.52	4.52	0
Other transportation	1.51	2.14	0.63
Communications	5.07	2.66	-2.41
Electricity	2.51	2.42	-0.09
Wholesale trade	2.84	7.84	5
Retail trade	0.68	4.93	4.25
Finance	3.18	6.76	3.58
Insurance	-0.28	0.44	0.72
Real Estate	1.38	2.87	1.49
Services	-1.12	-0.19	0.93
Personal services	-1.47	1.09	2.55
Business services	-0.16	1.69	1.85
Health services	-2.31	-1.06	1.26
Other services	-0.72	-0.71	0.01
Industries by intensity of IT use			
Intense IT use	2.43	4.18	1.75
Less intense IT use	-0.10	1.05	1.15
Finance, Insurance & Real Estate	1.70	2.67	0.97

The CEA studies have also shown that this positive effect in labor productivity is related with even better investments on IT. For instance, as it is demonstrated in the above

table, the average growth rate of labor productivity in the time period between 1995 and 1999 concerning the high-tech businesses, is four times as big as that of the low-tech companies. The findings of the aforementioned research are reinforced by the study of Stiroh (2001), who compared the production benefits during the 90s in 61 industrial sectors and found that in the 2/3 of the cases there was positive change in labor productivity after 1995. Moreover, he concluded that the high intensity IT industries had 1.3% higher acceleration in the growth rates of labor productivity than the rest. A study by the McKinsey Global Institute (2001) showed that 38 industries that correspond to the 70% of GDP, also had positive change in productivity after 1995. The capstone of the above is founded in the study of Triplett and Bosworth (2002), which focused on 27 industries in the services sector. It was the first study to shed light in this neuralgic section of the economy with such accuracy and recognizes the impact of IT and other factors in the production growth. An instant conclusion is that after 1995, most of the high-tech companies in USA belong in the services sector and the positive effect in their productivity has surpassed that of other sectors. All the above are of major importance as they show that the improvement in productivity, mainly after 1995, is significant and broad-based, affecting the whole of the economy and getting out from micro level. According to the view of Triplett and Bosworth (2002), this improvement often don't originated from new investment on IT, but from IT that existed a priori for over two decades but hadn't been reclaimed properly so as to bring the expected results.

National Level

The findings of the former studies show the contribution of many factors in economic growth at corporate and industry level that, as many of them proved, may be able to explain to an extent the national growth as well, but the key point in this situation is the as specific as possible effect on IT capital both in terms of labor productivity and general growth. The first studies in national level during the 80s and in the beginning of the 90s, didn't show any notable contribution of IT in productivity and economic growth. This result however, is justified to a high grade from the fact that IT investments occupied only a small portion of the capital stock in the economy so as to have a crucial role (Sichel 1997). For example, IT as part of the total investment in capital in US dollar terms, was at 3.5% in 1980 and at 9% in 1990. During the 90s however, IT investments grew drastically reaching 22% of the total capital invest in the US economy. This fact has it's origin in the constantly reducing price of IT products per 17% in annual basis during the period 1959-1995 and 32% in 1995-9

(Jorgenson 2001), pushing many companies to the replacement of other forms of capital with IT. These very important investments on IT had multi-significant effect on economic growth as it is conceivable from the following data. Labor productivity in USA that formerly had an annual growth rate of 1.5% in the period 1973-1995, it almost triple sized at the level of 3.1% per year from 1995 until 2000. Similarly, GDP increased per 3% in annual basis the first period while it reached 5% the last five years of 2000 (CEA 1001).This increase is proved in a lot of macroeconomic researches on the effects of IT investments and even by many scholars that previously had an opposite opinion,showing the large impact on economic growth at national level.A proof of the continuously positive and long-run effect of IT investments in macro level is the data that are cited in the following Table 2.

Table 3: The contribution of IT to GDP growth and productivity

Jorgenson & Stiroh (2000-1)	**1959-1973**	**1973-1995**	**1995-1999**
GDP growth (annual rate)	4.32	3.04	4.08
Capital Contribution (% of total)	33	50	71
IT contribution to GDP growth	4	13	28
Productivity growth (annual rate)	2.94	1.40	2.11
IT contribution to productivity growth	6	27	42
Oliner & Sichel (2000)		**1973-1995**	**1995-1999**
GDP growth		2.99	4.82
Capital contribution		42	38
IT contribution to GDP growth		17	23
Productivity growth		1.52	2.67

IT contribution to productivity growth		31	41

While therefore, the initial studies indicated a moderate contribution of IT to the rates of economic growth and productivity, 4% and 6% respectively, most recent highlighted a greater and more substantial effect. Specifically, the period 1973-1995 Jorgenson and Stiroh (2000) found that 13% from the 3.04% of economic growth and 27% from the 1.4% of the labor productivity rate is attributed to IT, while Oliner and Sichel (2000) found even greater figures as shown in the following tables.

Table 4: Productivity Growth Rate

	Time period	**France**	**Germany**	**Italy**	**Holland**	**USA**
Labor	**1991-1995**	**1.79**	**2.70**	**2.95**	**1.96**	**1.50**
	1996-1999	**1.37**	**1.53**	**0.86**	**0.53**	**2.60**
Total	**1991-1995**	**0.87**	**1.83**	**1.98**	**1.20**	**0.92**
	1996-1999	**0.83**	**0.97**	**0.45**	**0.47**	**1.47**

Source: Oliner and Sichel (2000)

Table 5: Contribution to GDP

		Time Period	**Contribution to GDP**			
			Information Equipment	**Software**	**Communication Equipment**	**Total Productivity**
Oliner / Sichel	**USA**	**1991-1995**	**0.25**	**0.25**	**0.07**	**0.92**
		1996-1999	**0.63**	**0.32**	**0.15**	**1.47**
Jorgenson / Stiroh	**USA**	**1991-1995**	**0.19**	**0.15**	**0.06**	**0.73**
		1996-1999	**0.46**	**0.19**	**0.10**	**1.24**

Source: Oliner and Sichel (2000), Jorgenson and Stiroh (2000)

The acceleration of the labor productivity rate between 1995-9 had its roots partially in the radical raise of IT expenditures. The main reason for this effect on productivity was

simply the fact that the accumulated IT capital represented a remarkable bigger share of the total capital stock in comparison to the previous periods. Thus, the contribution of IT on economic growth reached the period 1995-9 the level of 28%, according to Jorgenson (2001) and 42% as for labor productivity. Additionally with the investments on IT, the propagation and wide use of internet and e-commerce have contributed positively. A study by Litan and Rivlin (2001) estimated the impact on productivity by the use of Internet between eight industrial sectors that make up for the 70% of US GDP. The results showed a positive reaction of 0.2 to 0.4 basic trend of the productivity rate. In spite of the fact that in the rest of the world there was a lack of significant research in the issue that we examine compared to that of USA, the key findings in the developed countries of Europe and Asia simulate the above. For instance, Schreyer (1999) made a research in the G-7 countries and found that IT had positive impact on productivity in all the countries of the group in the period 1990-6. Another study by OECD in 2000 by Daveri updated and extended the research in 18 countries. Despite the individual differences between the two studies, the final results were similar.

In conclusion, the big reduction in the price-return ratio of IT equipment has motivated an increase in the investments of IT in the US economy and the rest of the world in the realm of the improvement of economic perfomance. The big boom in the investments on IT from the mid 90s and therefore, led to an acceleration of the rates of labor productivity and economic growth.

Concluding Remarks

As perceived from the aforementioned, the multi-significant issue of the relation between IT and economic performance stands in the foremost of the scientific attention over the last decades and is a key term in the research field of the telecommunications and informatics. Its importance is also proved by the fact that from the less than 12 studies during the 80s, we reached the over 50 in the 90s. The research concerning the results of IT investments is complicated containing a number of analytic tools so as to study a plethora of companies, industries and countries. Beyond the complexity of the issue, three fundamental conclusions are emerging from the previous review.

First of all, the productivity paradox as initially formulated by Robert Solow in 1987, fall. A large number of studies proved the important effect of IT investments on corporate, industrial and national productivity showing that information technology plays a crucial role.

Secondly, in spite of the fact that the so called "New Economy" and it's benefits pull the attention of the mass media at the end of the 90s, IT investments actually strengthen productivity for over three decades period.

Thirdly, and mainly concerning companies, while the results of IT investments are in general positive, there is a wide scale of performance among different enterprises. Some of them focus on the temper of the companies, while additionally, there is strong evidence that investments in organizational capitals due to managerial practices, like the decentralization of decision making, the education of the staff and the restructuring of the corporate procedures, have catalytic effect on the results of IT investments. The value of IT should be examined in relation with such investments in organizational level and must be treated as supplementary. This is justified by the fact that IT isn't just a simple tool for automation of the existing procedures, but is mainly an instigator for changes that can lead to productive profits.

As the Solow paradox has been solved, this review and evaluation of the studies suggests that the issue of IT returns is much more complicated from the initial estimation and therefore, more research is needed to shed light on several grey areas of the researches, mainly the issues of the measurement of inputs and outputs at corporate and national level. Improved methods of measurement, especially in terms of software and capital such as investments on R&D and human capital are a first step. An even more important but difficult step is the measurement of the outputs. This is of major significance for the services sector that dominates in our days, where the problem becomes bigger. IT results in this area that consists of the 2/3 of the US economy, become less understood from all the other sectors and possibly are underestimated. The right measurement is defined by the economic theory and always depends on the available statistical data. The measuring process of IT consists of three steps: 1) The quantity measurement in current prices (nominal terms) 2) The price measurement adjusted for quality differences and 3) The measurement of real sizes in fixed prices adjusted for quality. In the first step, the main issue is the right measurement of the nominal added value per sector. For economic aspect, the second step is much more difficult because contrary to the general trend of inflation to other goods and services, in IT we encounter deflation owing to the quality improvements. The problem is that the structure of suitable price indicators prerequisites the readjustment of the observable prices for quality changes. The theory suggests two different methods for the measurement of fixed quality prices: 1) the matched model and 2) the hedonic method (hedonics) that is the dominant. The following table provides an indication of the degree that hedonic methods are adopted by nine

representative countries of OECD. Only USA has applied such methods for software and communications equipment.

Table 6: Comparative table

	Software	Information Equipment	Communication Equipment
Australia	No	US hedonic index for computers adjusted for changes in exchange rates	No
Canada	They don't have own measurements. They adjust & use US hedonic indices	Hedonic indices for computers and peripherals	No
Finland	Average (50:50) profit index of computer sector & US hedonic price index for software	Not referred	Not referred
France	No	Hedonic index for computers: combination of hedonic measures for France & US hedonic price index adjusted for changes in exchange rates	No
Germany	No	No	No
Italy	No	No	No
Japan	No	Hedonic index for computers only	No
United Kingdom	No	No	No
USA	For stock software: hedonic index For software under notice: average non-hedonic index and stock software index	Hedonic index for computers and peripherals	Hedonic index for switching equipment

Source: Colecchia and Schreyer (2001)

Moreover, the present study has given priority to some areas for future research. Three are the most important for professional practice. First of all, more analysis of the mechanisms is necessary through which some companies receive high benefits from IT investments and particularly, from these of supplementary assets. The second priority explains why some industries of IT capital intensity haven't shown benefits in productivity despite the large IT investments. These two priority areas shall help in the direction of the settlement of some of the most difficult and measuring issues. The third part is the paradox of profitability or else the failure of the studies to show a positive relation between IT investments and the measures of financial performance. It is very important for better data bases to be created and also for models to control the additional factors that affect profitability.

Finally, the above findings must me combined with recent facts in the international economic scene such as the current financial crisis. From the mid 00s and more drastically the last 3 years, IT investments have followed a declining route mainly due to the general economic recession that the world economy has encountered with the highlight of the current crisis. Likewise, the fall of many Internet related companies had a negative impact in two ways: not only their own IT investments disappeared but also reduced the competition pressure to the other companies so as to invest on technology.

Nevertheless, IT investments shall continue to exercise positive effect on productivity as shown by the studies not only directly but indirectly too. The indirect way is documented by the fact that companies that invested on IT are tied down in complementary managerial and organizing practices that improve the benefits they enjoy from IT investments, discovering and utilizing the returns that Internet and other networks provoke achieving notable profits in productivity.

The final conclusion is summarized in the words of the Nobel prized economist Joseph Stiglitz for the US economy and the role of IT, that enclose all the meaning of the aforementioned studies:

"For many reasons, the foundations of the US economy remain strong and strengthened further during the 90s. The New Economy is real, in spite of the fact that its value has been exaggerated. The new technologies have caused increases in productivity that will continue to make a huge difference in our living standards".

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